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Retrofit Fluorescent Dimming with Integrated Lighting Control – Economic and Market Considerations

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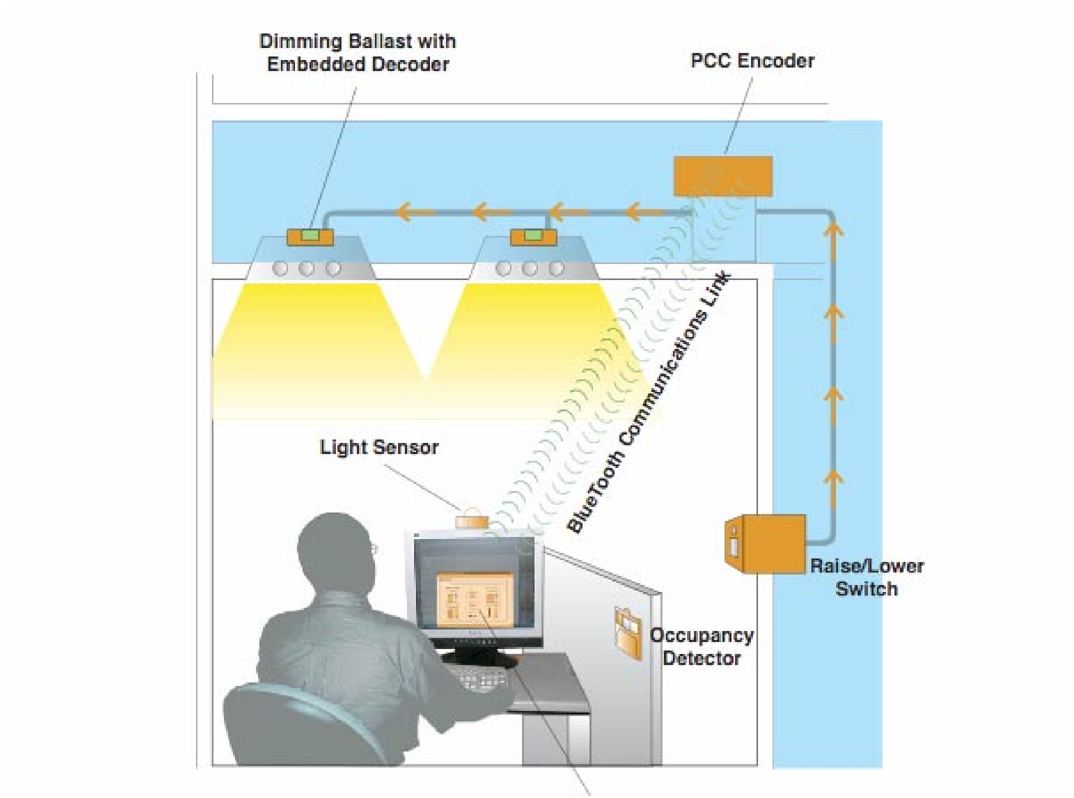
Retrofit Fluorescent Dimming with Integrated Lighting Control - Economic and Market Considerations

The Product

A lighting control system that will reduce lighting demand in existing commercial buildings by implementing automatic control strategies and improved manual control.



Function

The objective of this project is to prototype an advanced lighting controller designed to bring low-cost control to existing commercial building lighting systems. The specific hardware to be prototyped will be designed to work with commercially available fluorescent lighting ballasts to form the core of a highly progressive, functional, and efficient lighting control system.

The system consists of a ceiling-mounted encoder capable of transmitting control commands over existing wiring, enhanced dimming ballasts that embed inexpensive decoders and a wall control touchpad. The system is being designed so that the changes to the existing overhead electrical system are minimized which minimizes installation costs for existing buildings.

One encoder is required for each circuit or switchleg to be controlled. It is anticipated that the encoder would be electrically and mechanically attached to the junction box present in most electrical distribution systems. It is anticipated that the decoders will be embedded into existing 0-10 VDC dimming ballasts by ballast manufacturers. The wall control touchpad will be a direct replacement for an existing wall switch, thus minimizing electrical work to the extent possible.

Features

The system will provide control of the lighting system using the following manual and automatic means:

1. Manual dimming control by occupant using wall-mounted dimmer
2. Manual dimming control by occupant using PC “virtual” control panel
3. Automatic lighting control using PC-connected environmental sensing suite as input
4. Utility-triggered load shedding via Intranet-connected PC
5. “Auto-pilot” mode, automatically enabled when PC, environmental sensing, or IP connection are off-line

Differentiation

The closest system with similar features is the Centura CN-100 control system from Leviton (www.leviton.com). What differentiates the proposed system is the elimination of the added low voltage control wiring required for the Centura system. Wiring errors are the hobgoblin of today’s control systems, so minimizing the amount of added wiring can make a significant difference in whether a system can or cannot be cost-effectively employed into existing buildings.

Target Markets

The target market for the proposed control technology is all commercial building floorspace that utilizes fluorescent lighting. The California Energy Commission defines 10 building types that make up this floorspace. The size of these sectors and the fluorescent lighting energy usage in each are:

Sector	Size (billions square feet)	Fluorescent Lighting Energy Consumption (BkWh)
Office	1.03	7.93
Retail	0.74	3.59
Hospital	0.24	2.3
Food Store	0.2	2.13
Miscellaneous	0.84	1.6
Warehouse	0.66	1.12
School	0.39	1.09
College	0.22	0.6
Restaurant	0.12	0.51
Hotel	0.22	0.28
Total	**4.6**	**21.2**

The California commercial building stock was about 4.6 billion square feet of floorspace in 2000. Fluorescent lighting systems for these sectors consumed 21 BkWh in 2000 at a cost to businesses and schools of about $2 billion annually. The proposed lighting control system is appropriate nationally as well as in California. The national market is roughly 10 times the size of the California market sector discussed previously. The technology may be also appropriate internationally, since technology issues tend to be similar in the U.S. as in other developed countries.

Energy and Demand Savings Potential

The proposed system saves energy and reduces demand through a number of means, both automatic and manual. A number of case studies of lighting controls in existing buildings have demonstrated the enormous energy savings potential of lighting controls. Lighting controls save energy by exploiting a variety of control strategies, especially: daylight linking, light level tuning, and scheduling. Load shedding is another key strategy for demand reduction. These strategies, and the best available estimate of the energy savings potential of each in a typical building application based on case studies, are given below.

Lighting Control Strategies and Estimated Energy Savings from Case Studies

Lighting Control Strategy	Strategy Definition	Estimated energy savings potential	Case Study References
Daylight-linking	Automatically lowering electric light levels in response to increased daylight levels	35% in daylit areas -- 12% averaged over daylit & non-daylit space	
Light level tuning	Reducing electric light levels according to occupant preferences	25%	
Load shedding, demand responsive	Reducing light levels in response to power capacity shortages	N/A. Saves little energy but significant benefits for power generation	
Scheduling	Turning lights off automatically after space is vacated	25% relative to manual switching	
All strategies combined		**50%**	

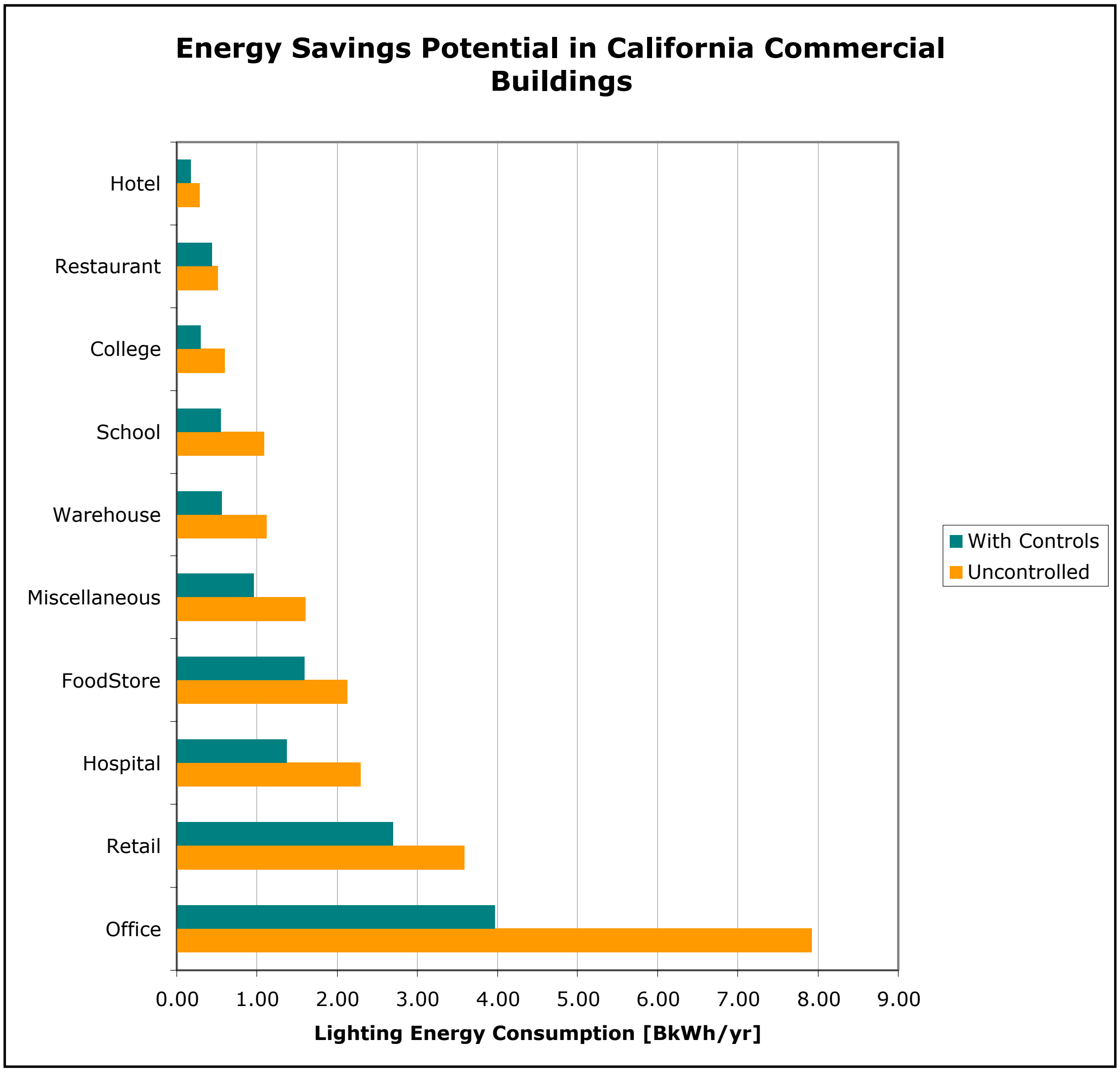
Daylighting. Thirty-five percent savings from daylighting controls in daylit spaces are typical of documented energy savings from available, monitored case studies. For example, the testing at the San Francisco Federal Building indicates that the savings potential from daylighting is between 16-41 percent (estimated annual savings). Since only a fraction of building space is daylit (estimate 35 percent), the 35 percent savings is diluted by 35 percent to obtain average energy savings of 12 percent across all floor space.

Tuning. Measurements at the National Center for Atmospheric Research [Mannicia 2000] suggest that the energy potential of light level tuning is about 15 percent. Measurements of the effectiveness of energy of bi-level switching [Rubinstein 1998] indicate that the savings from tuning could be as high as 25 percent if the switches are well utilized by the occupants. Studies on the energy saving impact on tuning light levels according to spectral content suggest a 25 percent savings from that technique alone.

Scheduling. Occupancy sensors will capture some savings and coupled with the use of intelligent dimming strategies will further increase the energy savings in many applications. LBNL assumed that integrated lighting controls would result in an additional 10 percent energy savings compared to that from occupant sensors alone.

All strategies combined. Based on the above studies, LBNL estimated that an automatic lighting control system combined with the above strategies in the identified target application space has the potential to reduce lighting energy consumption by about 50 percent on average over the year compared to a lighting system of equivalent efficacy that is not controlled.

Although the system is designed for existing buildings, it would be suitable for new construction and would be more economical to install as well, because most of the installation labor charges would have occurred even if a standard lighting system were installed.



Summing the above data, LBNL estimated that the target commercial application space for the technology is 4.6 billion square feet in California commercial buildings. At present, fluorescent lighting systems in this market consume 21 BkWh annually at a cost to California businesses and institutions of $1.9 billion (in 2000). The average lighting energy intensity in this sector is 4.5 kWh/square foot/yr (21 BkWh/yr / 4.5 kWh/square foot/year). Using an accepted operating hours of 3200 hours per year, an average power density of 1.43 watts/square foot is imputed.

Non-Energy Benefits

One benefit of the proposed system is the ability of the occupant to dim their overhead lights to whatever they choose. Although research in this field is sketchy, there is evidence that improved occupant control over lighting and environmental systems in buildings has positive non-energy benefits for occupants in terms of improved comfort and satisfaction with the lighting system.

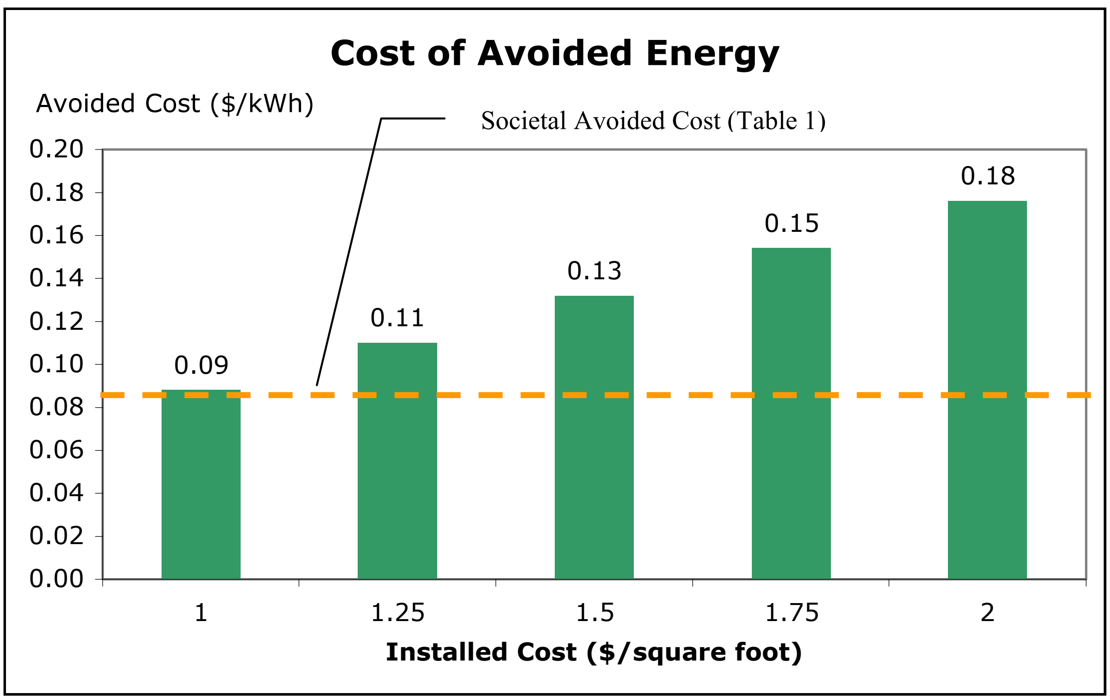
There are many benefits to improved occupant comfort and satisfaction although quantification is difficult:

1. Rental space with added comfort features may command a higher rental value
2. Improved employee retention
3. Accommodation of modern workplace practices such as "hot-desking", where one workstation is used by more than one individual on different days

Societal Avoided Costs (for potential incentive payments)

Making some assumptions about energy saving potential and the energy intensities in the target sector, the societal avoided energy costs for the project can be computed. First, the energy intensity is obtained by dividing the fluorescent lighting energy consumption in the aggregate total market (21 BkWh) by the applicable floorspace (4.6 billion square feet in CA).

Energy Intensity:	4.5 kWh/sf-yr
Hours of Operation:	3200 hours
Imputed Power Density:	1.43 w/sf
Energy Savings: 50%	
Equivalent Power Density Reduction:	0.71 w/sf
Time Horizon for Analysis:	5 year



From this analysis, LBNL can state that if the new system cost $1/square foot to install, this results in an avoided cost to the end-user of $0.09/kWh. Since that is essentially identical to the average societal avoided cost from Table 1, it follows that no additional utility incentives would be required. However, if the installed cost is, for example, $1.75/square foot, the avoided energy cost to the end-user is $0.15/kWh, considerably higher than the average societal avoided cost of $0.09/kWh. In this case, it would be logical to seek a utility incentive for the technology investment which would "buy-down" the cost of the investment so that effective avoided cost to the end-user was $0.09/kWh. In the example shown, the utility would rebate $0.75 out of the $1.75/square foot total investment (43 percent) to “buy-down” the end-users cost.

Product Costs and Uncertainties

The system consists of three basic components: encoder, decoders and wall controls. The decoder has the greatest cost pressure since one decoder is required for each ballast or fixture to be controlled. LBNL will work with a ballast manufacturer to obtain realistic estimates as to what the manufacturer’s cost would be to embed the decoder directly into a modern dimming ballast. The wall control is similar to other existing raise/lower wall switches and the cost can be easily estimated. The encoder design has not yet been thoroughly tested so it is premature to perform detailed cost evaluation. Once the design of the encoder has been fixed, LBNL will work with a controls manufacturer to obtain a manufacturer’s cost estimate. The cost of the encoder has the greatest uncertainty associated with it.

Installation-Related Costs

The installation of the system requires: 1) replacing the existing ballasts in the ceiling system with dimming ballasts with embedded decoders, 2) replacing the wall switch with the wall control and 3) attaching the encoder to the existing junction box above the wall switch. Each of these steps requires an qualified electrician, but the actual labor activities associated with installing the new system all have analogs in standard practice. In terms of labor expenditure, it should be no more expensive to install a PCC ballast than a standard ballast. Replacing the existing wall switch with a wall control would also be similar in labor cost. Installation of the encoder may the costliest part, since the junction box where the installer would mount the PCC encoder is often above a false ceiling with possibly restricted access. In terms of labor, LBNL anticipates that installing the encoder would be similar to installing another junction box in the ceiling. The Means Cost Guide can be used to estimate all of the above labor costs.

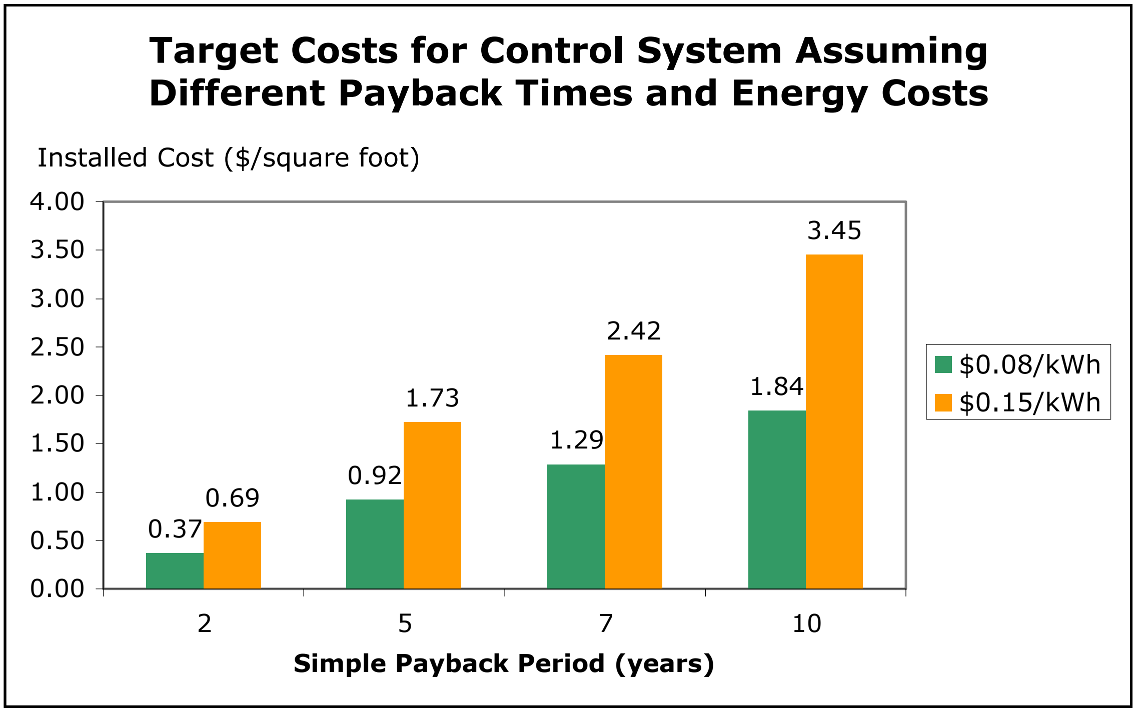
Commissioning costs would likely be incurred in the proposed system. LBNL does not have the necessary information to estimate commissioning costs for the system at this time.

Effects on O&M Cost

LBNL anticipates no significant positive or negative changes in maintenance, replacement or repair costs relative to a standard lighting system.

Payback Period and Return on Investment

Because the system costs are not yet fixed, LBNL cannot perform a standard payback analysis on this technology. However, armed with estimates of the anticipated energy reduction for the technology, the installed cost can be “back calculated” to determine what amount would have to be to meet to achieve desired payback criteria (two or five year payback, for example). The graphic below summarizes the results of this analysis and plots the target costs for the control system assuming energy costs of $0.08 and $0.15/kWh and payback periods of two, five, seven and 10 years.



If the range of "acceptable" installed costs is $1.00 - $2.00/square foot, then the payback for the technology is probably about five years. For the technology to pay back in two years, it would require a target installed cost of $0.37/square foot and $0.69/square foot for energy costs of $0.08 and $0.15/kWh, respectively. It is unlikely that the technology will come down to that price even in a mature market.

The Bottom Line: Compilation of User Costs, Incentives, Savings and Payback

The major quantifiable economic benefit for the end-user is primarily in the avoided energy costs as a result of the much lower energy consumption the new system. As estimated earlier, the expected energy savings is 50 percent if all control strategies are employed. Applied to a basecase energy intensity of 4.6 kWh/square foot/year results in a reduction in energy intensity of 2.3 kWh/square foot/year. The economic value of this reduction in energy use is proportional to the cost of electricity to the commercial end-user (assumed to be $0.08/kWh or $0.15/kWh).

As indicated earlier, the proposed technology would not likely pay back in only two years. At a more realistic 5-year payback, the investment would be cost-effective for the end-user if the installed costs were $0.92/square foot (with energy costing $0.08/kWh) or $1.72/square foot with energy costing a more typical $0.15/kWh.

LBNL cannot quantify the economic value of the non-energy benefits except to note that they may be equal in magnitude to the avoided energy costs. It is assumed that no change in maintenance costs would occur.